EEG RESPONSES TO LOW-LEVEL CHEMICALS IN NORMALS AND CACOSMICS

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Recent studies from the University of Arizona indicate that normal subjects, both college students and the elderly, can register the presence of low-intensity odors in the electroencephalogram (EEG) in the absence of conscious awareness of the odors. The experimental paradigm involves subjects sniffing pairs of bottles, one containing an odorant (e.g. isoamyl acetate) dissolved in an odorless solvent (water or liquid silicone), the other containing just the solvent, while 19 channels of EEG are continuously recorded. For the low-intensity odor conditions, concentrations are adjusted downward (decreased) until subjects correctly identify the odor bottle at chance (50%). The order of odorants, concentrations, and hand holding the control bottle, are counterbalanced within and across subjects. Three previous experiments found that alpha activity (8–12 hz) decreased in midline and posterior regions when subjects sniffed the low-intensity odors. The most recent study suggests that decreased theta activity (4–8 hz) may reflect sensory registration and decreased alpha activity may reflect perceptual registration. In a just completed experiment involving college students who were selected based on combinations of high and low scores on a scale measuring cacosmia (chemical odor intolerance) and high and low scores on a scale measuring depression, cacosmic subjects (independent of depression) showed greater decreases in low-frequency alpha (8–10 hz) and greater

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2. Abbreviations: electroencephalogram (EEG).

3. Key words: cacosmia, EEG, low-level chemicals, multiple chemical sensitivity, olfaction, sensitization, subliminal.

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increases in low-frequency beta (12–16 hz) to the solvent propylene glycol compared to an empty bottle. Topographic EEG mapping to low-intensity odorants may provide a useful tool for investigating possible increased sensitivity to specific chemicals in chemically sensitive individuals.

INTRODUCTION

The olfactory system is an exquisitely sensitive sensory system. Although individuals vary in the minimal concentrations necessary for the conscious registration of a given odor, the olfactory receptors are capable of detecting individual molecules and generating corresponding neural signals. Most chemoreceptors within the body do not generate neural signals that can be experienced consciously (e.g., perceptual awareness has not been reported for carbon dioxide receptors in the cardiovascular system). It is reasonable to hypothesize that the olfactory system may register a broader range of intensities and molecules than is typically experienced consciously. Early research at Yale University suggested that subthreshold concentrations of an odorant could be registered in the EEG (Lorig et al., 1990), and recent studies from Washington and Lee University indicate that behavioral and cognitive effects can be observed for undetected odors as well (Lorig, 1994). Recent research from the University of Arizona (Schwartz et al. 1992a,b,c, 1993, 1994a,b) suggests that subthreshold concentrations of specific odorant molecules can be detected in the EEGs of normal college students and the elderly, and that subjects showing a specific anosmia for androstenone nonetheless register the presence of androstenone in their EEGs.

There are numerous implications of these findings for basic and applied research in the areas of olfaction, the study of conscious and unconscious processes, and chemical sensitivity. One major implication and advantage of using low-intensity odors with populations claiming to be chemically sensitive is that this procedure removes expectancy and potential "placebo" explanations from the findings that are obtained. Low-intensity odors make it possible to avoid using "masking" odors to test for chemical sensitivity. In addition, low-intensity odors may make it possible to distinguish between malingering and nonmalingering patients. Preliminary analyses of an experiment examining EEG responses to low-intensity odors in subjects scoring high and low in cacosmia and high and low in depression (a 2 X 2 design) suggests that quantitative EEG mapping may be a useful tool in research on chemical sensitivity (Schwartz et al., 1994b).

Research in olfaction, especially involving low-intensity odors, has inherent conceptual and methodological problems (Lorig, 1989). Research in chemical sensitivity has even more conceptual and methodological problems (Bell et al., 1992). Consequently, combining these two areas is especially challenging. The research described in this paper, though suggestive and promising, should be viewed as exploratory.

First, we will review studies presented at the 1992 and 1993 Association for Chemoreception Sciences meetings documenting EEG registration of subthreshold odors and of androstenone

in androstenone anosmic subjects. These studies set the stage for research on chemical sensitivity, and therefore they are reviewed in some detail. Then we will report the results of analyses conducted to date on two studies that were presented at the 1994 Association for Chemoreception Sciences and the American Psychiatric Association meetings, indicating EEG registration of subthreshold odors in normals and increased EEG registration of the solvent propylene glycol in subjects claiming to be cacosmic.

SUBTHRESHOLD AND ANDROSTENONE ANOSMIA STUDIES

In the first experiment (Schwartz et al., 1992a), 19 channels of EEG were recorded from 54 elderly subjects between the ages of 60 and 70 while they sniffed pairs of flasks for 8 seconds each, presented sequentially, with eyes closed. One of the flasks contained concentrations of isoamyl acetate predissolved in propylene glycol and then diluted in 50 ml water. The concentrations increased sequentially from subthreshold (3 concentrations) through threshold (4 concentrations) to suprathreshold (4 concentrations). The other flask contained only the solvents (the control condition). The order of experimental and control flasks was counterbalanced across subjects. At the end of each trial, subjects guessed which flask contained the odor and rated their confidence and perceived intensity on a scale from 0 to 10. In all the experiments, EEG was amplified and analyzed using the NeuroSearch-24 EEG system. In this experiment, EEG was sampled at 128 hz, spectral analyses were performed, and alpha power (8–12 hz) was displayed in topographic maps. In normal subjects, decreases in alpha typically reflect cortical activation [as do decreases in theta (4–8 hz) and increases in beta (> 12 hz)]. Correct guesses were 92% for the suprathreshold trial and 52% (chance) for the subthreshold trial selected for analysis.

When subjects smelled the suprathreshold concentration, significant EEG alpha frequency (8–12 hz) decreases were observed in anterior, mid central, and posterior regions, whereas when subjects smelled the subthreshold concentration, significant alpha decreases were observed only in the mid central and posterior regions. All significant effects were at least $p < 0.05$. The data were interpreted as supporting the hypothesis that older adults can be sensitive to odors at subconscious levels, and that conscious perception may involve the frontal regions as originally hypothesized by Luria (1973).

In the second experiment (Schwartz et al., 1992b), 19 channels of EEG were recorded from 10 college students while they sniffed pairs of flasks for four seconds each. One of the flasks of each pair contained common odorants used in olfaction research, isoamyl acetate, di-acetyl, or coumarin, dissolved in 50 ml of water. The other flask contained 50 ml water (the control condition). In the first three sessions, thresholds were determined for the three odors. Two subthreshold concentrations, one "gray zone" (at threshold) concentration, and two suprathreshold concentrations were selected per odor per subject. Over the next three sessions, EEG data were collected during the 6 trials of each odor at each concentration. The order of odors, concentrations, and experimental and control flasks was counterbalanced within subjects and across sessions. At the end of each trial, subjects guessed which flask

contained the odor (detection), what the odor was (discrimination), and rated their confidence on a scale from 0 to 10. EEG analyses were performed on the highest subthreshold and suprathreshold concentrations. Correct odor detection was 95%, 95%, and 98% for the suprathreshold concentrations of the three odors, and was 43%, 45%, and 51% (chance) for the subthreshold concentrations.

Across all odors, when subjects smelled the suprathreshold concentration, significant EEG alpha (8–12 hz) decreases were observed in anterior, central, and posterior regions, whereas when subjects smelled the subthreshold concentration, significant EEG alpha decreases were observed only in the central region (somewhat right lateralized). These data replicated and extended the initial findings in the elderly.

In a second experiment involving elderly subjects (Schwartz et al., 1992c), the question was raised whether subjects who did not report smelling androstenone (a purported male sex pheromone) would nonetheless show EEG registration of the molecule. Nineteen channels of EEG were recorded from 33 subjects between the ages of 60 and 70 while they sniffed bottles containing different odors for 60 seconds per bottle. Two bottles contained concentrations of androstenone dissolved in silicone. Two bottles contained either liquid silicone or water (control conditions). Four bottles contained essential oils. The order of odor presentations was counterbalanced across subjects. Subjects rated from 0 to 10 their level of relaxation, the intensity and pleasantness of the odor, how masculine or feminine the odor smelled, and the percentage of time (0 to 100%) they were aware of the odor. Osmics rated the intensity of the odor and the percent time they were aware of the odor higher for androstenone than silicone and water (5.4 vs. 1.9; 72% vs. 25%). Anosmics rated the intensity of the androstenone and the percent time they were aware of the androstenone similar to silicone and water (2.0 vs. 1.4; 28% vs. 24%). Thirteen subjects were osmic for androstenone, 20 were selectively anosmic for androstenone. The anosmia was highly selective for androstenone since the ratings of the essential oils were virtually identical comparing the osmic and anosmic groups (7.3 and 7.8; 82% and 88%).

Analysis of the EEG of the subjects anosmic for androstenone compared to the control conditions revealed significant, selective EEG alpha decreases in the right central region when smelling androstenone. Further evidence for central nervous system processing of androstenone in the androstenone anosmic subjects was observed in the mood data. Both osmic and anosmic subjects rated themselves feeling significantly less relaxed during the androstenone than during the control conditions (osmics 6.3 vs. 7.2; anosmics 6.4 vs. 7.1), even though the anosmics did not report smelling the androstenone. The EEG findings for the anosmic androstenone subjects curiously paralleled the EEG findings for the subthreshold odorants.

The subthreshold and androstenone findings were replicated and extended in a subsequent experiment (Schwartz et al., 1993). Nineteen channels of EEG were recorded from 52 college students while they sniffed pairs of bottles. One bottle per pair contained isoamyl acetate or

androstenone dissolved in odorless silicone. The other bottle contained silicone (the control). Subjects were prescreened for isoamyl acetate and androstenone detection and invited for EEG testing if they consistently detected isoamyl acetate and either detected androstenone (osmic) or failed to detect androstenone (anosmic). EEG was collected during two two-second sniff periods per bottle for eight trials per odor at two concentrations, one suprathreshold and one subthreshold (subthreshold androstenone was determined by androstenone osmic subjects). The order of odors, concentrations, experimental and control bottles, and hand, was counterbalanced within subjects. After each trial, subjects indicated which bottle contained the odor (detection), rated their confidence of detection and the odor's intensity on scales from 0 to 10. In this experiment, EEG was sampled at 256 hz rather than 128 hz. Correct odor detections for the suprathreshold concentrations were 99% for isoamyl acetate, and 99% for androstenone osmics and 41% for androstenone anosmics. Correct odor detections for the subthreshold concentrations were 48% for isoamyl acetate and 57% for androstenone (50% is chance).

When subjects smelled suprathreshold isoamyl acetate, significant alpha decreases were observed in anterior, central, and posterior regions, whereas when subjects smelled subthreshold isoamyl acetate, significant alpha decreases were observed primarily in the central region to sniff two (post hoc analyses of the first two studies revealed that the largest effects for subthreshold alpha also occurred to sniff two). Significant alpha decreases were also observed to suprathreshold androstenone in both osmic and anosmic subjects in both sniffs, whereas significant EEG alpha decreases were observed to subthreshold androstenone in both groups to sniff one. The data replicated and extended the previous findings suggesting that humans can register odors at subthreshold levels, and that androstenone anosmia may involve cortical inhibition of olfactory perception.

In the most recent study (Schwartz et al., 1994a), 19 channels of EEG were recorded from 86 college students, replicating the previous experimental protocol with three important additions. The first was that the subthreshold odors were administered double-blind rather than single-blind (the previous studies all used single-blind procedures). The second was that the number of subthreshold isoamyl acetate trials was increased from 8 to 16. In addition, EEG was spectral analyzed in 2-hz bands instead of 4-hz bands, and analyses were performed on low-frequency theta (4–6 hz), high-frequency theta (6–8 hz), low-frequency alpha (8–10 hz), and high-frequency alpha (10–12 hz).

Figure 1 (Color Plate 2) displays topographic EEG maps subtracting control bottles from the odor bottles for the subthreshold isoamyl acetate trials (n = 16) for the 86 subjects. Subtraction maps are necessary to remove the effects of hand posture, breathing, attention, and registration of the control solvent from the EEG, leaving just the effects of the registration of the isoamyl acetate. The top four maps reflect sniff one, the bottom four maps reflect sniff two. The four EEG bands are all drawn on the same scale. The color scheme shows that reds and whites reflect increases in theta or alpha, while blues and blacks reflect comparable magnitude decreases in theta or alpha.

It can be seen that for low-frequency theta (4–6 hz), EEG registration of the subliminal odor occurred on the first sniff, especially in the central and posterior regions, more on the right side. For high-frequency theta (6–8 hz), EEG registration of the subliminal odor occurred on both sniffs, again central and more posterior on the right side. For low-frequency alpha (8–10 hz), some evidence for EEG registration was obtained, more central and right sided, somewhat for both sniffs. For high-frequency alpha (10–12 hz), EEG registration was obtained especially for sniff 2, and the effect was central and more anterior on the right side. These effects were all statistically significant, at least $p < 0.05$.

Time and space do not permit a more detailed presentation of these data. However, three additional sets of analyses should be summarized briefly:

1. When the 16 trials for each subject were split into hits and misses, significant EEG effects, especially for theta, were replicated for misses when subjects guessed incorrectly that the odor was in the control bottle (which they did on half the trials). Hence, the EEG effects, especially theta, reflected registration of the low-level odor regardless of cognition or belief.
2. When the control trials were compared in terms of belief (trials where subjects thought the odor was in the control — i.e., false positive trials), belief in the absence of odor showed virtually no effect for EEG theta, and showed some effect for EEG alpha. However, belief showed up more in the anterior (frontal regions), where as odor effects showed up primarily in the central and posterior regions. *Hence, belief can be distinguished from odor effects.*
3. When subjects were split into high,- medium-, and low-performance subgroups based on their overall guessing accuracy, the EEG effects were replicated across subgroups for theta. Alpha effects were strongest in the high performance subgroup. However, the groups were identical in ratings of perceived intensity of the odors and perceived confidence of their guesses! Hence, the high performance group reflected a high "sensitivity" group in the absence of conscious awareness. EEG patterns for high sensitive normal subjects may be relevant to the applications of this paradigm to the study of cacosmics and chemically sensitive individuals.

One final point should be mentioned. When ratings of intensity for hit trials versus miss trials (on a 0 to 10 scale) were analyzed separately for the three performance groups, a subtle yet significant difference in reported intensity was observed for the groups (high 1.98 vs. 1.75; medium 2.20 vs. 1.99; low 1.74 vs. 1.65, $p < 0.03$). Hence, even though subjects guessed at chance level, and their reports of odor intensity were minimal, subtle differences between hit versus miss trials were revealed. Since the EEG effects were observed in the miss trials as well as the hit trials, the EEG results could not be explained by these subtle effects. However, as will be seen below, subtle differences in awareness were also found in subjects perceptions of different chemicals included in the design as "control" stimuli, and some of these subtle perceptions were different between noncacosmic and cacosmic subjects.

PRELIMINARY RESEARCH IN CACOSMICS

Bell et al. (1993a,b,c) have conducted a series of studies indicating that it is possible to identify in normal populations subjects reporting symptoms of illness to common environmental chemical odors. Although subjects scoring high in cacosmia tend to indicate higher levels of depression and anxiety, the correlations are small and account for only a small proportion of the variance in cacosmia scores. Hence, it is possible to find subjects who score high in cacosmia and low in depression, subjects who score low in cacosmia and high in depression, subjects who score high in both cacosmia and depression, and subjects who score low in both cacosmia and depression. We have hypothesized that cacosmia and depression are separate yet interactive processes, and that quantitative EEG analyses of responses to low-level chemicals will differ for cacosmia and depression (Bell et al., 1992).

An experiment was conducted on 66 subjects selected for combinations of high and low cacosmia and high and low depression (Schwartz et al., 1994b). Subjects were initially chosen from the top and bottom 40% for depression using the Symptom Checklist 90 Revised and for identifying three of five chemicals as causing illness "sometimes" or more, or identifying no chemicals as causing illness. These subjects were then screened over the telephone. Cacosmia was reassessed using a five-item true/false scale, depression was reassessed using a short depression subscale, and health was assessed using assorted health history questions. In order to be chosen for the high-cacosmia groups, subjects had to identify at least three chemicals as causing illness. For the low-cacosmia groups, all chemicals had to be identified as not causing illness. To be selected for the depression groups, subjects had to have a total of eight for the three Weinberger questions and the "I expression depression" question (five point scale). To be selected for the nondepressed groups, subject's depression scores had to be less than eight. Students were disqualified if they were smokers, if they used prescription or nonprescription drugs regularly, if they had a cold or flu, stuffy nose, asthma, anaphylactic shock, epilepsy, diabetes, heart, liver or kidney disease, or suicidal feelings. Table 1 shows the mean ages, the number of females and males, and the mean cacosmia scores, for the four groups.

TABLE 1. Mean Age, Sex Ratio, and Cacosmia Scores for Cacosmia (C) and Depression (D) Combinations

Group	Age	Females/Males	Cacosmia
Controls (Low C/Low D)	19.7	9/9	7.22
Cacosmics (High C/Low D)	18.9	10/5	13.21
Depressed (Low C/High D)	18.7	9/6	8.60
Cacosmic Depressed	18.2	16/2	13.33

It can be seen that all four combinations of cacosmia and depression scores were obtained, and that the groups were identical in ages. The cacosmia groups had somewhat more females than the noncacosmia groups.

To increase the duration of exposure for subjects, the paradigm used followed the design in Schwartz et al. (1992c) examining EEG registration of androstenone in androstenone anosmics in the elderly. Subjects smelled bottles containing different chemicals for one minute periods with eyes closed. The bottles were held by a metal stand. The experiment included three "control" bottles (an empty bottle and two bottles containing the solvents used in the study — distilled water and propylene glycol), and four chemical mixtures (low and moderate concentrations of butanol in distilled water, and low and moderate concentrations of galaxolide — a musk odorant — in propylene glycol), randomized across subjects.

After each trial, subjects made a series of ratings using the numbers 0 through 10 regarding the intensity of the odor, the duration of the experience, the pleasantness of the odor, odor identification, and moods. Analyses to date have been completed on the EEG data for the three control bottles for theta (4–8 hz), low-frequency alpha (8–10 hz), high-frequency alpha (10–12 hz) and low-frequency beta (12–16 hz).

Significant odor effects (empty versus distilled water versus propylene glycol) were obtained for each of the four bands, primarily in central and posterior regions. In addition, significant interactions with cacosmia were obtained for low-frequency alpha ($p < 0.05$ for the posterior temporal/parietal sagittal strip, and $p < 0.055$ for the occipital strip) and low-frequency beta ($p<.04$ for the posterior temporal/parietal sagittal strip, and $p < 0.007$ for the occipital strip).

Figure 2 (Color Plate 3) displays distilled water minus empty bottle topographic EEG maps (top) and propylene glycol minus empty bottle topographic EEG maps (bottom) separately for the noncacosmics (left) and cacosmics (right), averaged over depression, for low-frequency alpha. As in the previous studies, subtraction maps were used to remove the effects of hand posture, breathing, attention and the smelling of air per se from the EEG, leaving just the effects of the registration of the solvents. The terms increase and decrease therefore refer to relative changes in EEG as compared to the empty bottle control.

It can be seen that the noncacosmics showed, if anything, relative *increases* in low-frequency alpha (red color), whereas the cacosmics showed clear *decreases* in low-frequency alpha in the posterior regions (black and blue colors). The maps suggest that the decreases in low-frequency alpha (relative to the empty bottle control) were greater for propylene glycol than distilled water (especially in more anterior regions). There were no significant interactions involving depression related to the chemicals in low-frequency alpha.

Figure 3 (Color Plate 3) displays distilled water minus empty bottle topographic EEG maps (top) and propylene glycol minus empty bottle topographic EEG maps (bottom) separately for the noncacosmics (left) and cacosmics (right), averaged over depression, for low-frequency beta. It can be seen that the noncacosmics showed relative *decreases* in low-frequency beta (black and blue) to both distilled water and propylene glycol, whereas the cacosmics showed clear *increases* in low-frequency beta in the posterior regions (red and white colors) to

propylene glycol, the chemical solvent. Interestingly, increases in beta have been reported for monkeys and humans exposed to the organophosphate sarin (Burchfiel and Duffy, 1982).

Significant effects for depression by bottle by EEG site were obtained for the anterior frontal sagittal strip ($p < 0.03$) and the temporal/central saggital strip ($p < 0.05$), but these effects did not interact with cacosmia. Moreover, the effects were completely opposite. Nondepressed subjects showed *increases* in low-frequency beta to distilled water and propylene glycol, whereas depressed subjects show *decreases* in low-frequency beta to distilled water and propylene glycol.

These preliminary findings suggest that "normal" subjects who report feeling sick when smelling certain chemicals, regardless of their perceived depression, show heightened EEG reactivity in posterior regions, especially to propylene glycol, as evidenced by decreases in low-frequency alpha and increases in low-frequency beta. These findings can not be explained by depression. Depression did not yield significant effects for low-frequency alpha, and the significant effects observed for low-frequency beta were in more anterior regions and were in the opposite direction (i.e., depressed subjects showed reduced EEG reactivity.

The present study has a number of weaknesses that qualify the interpretation. First, the three bottles were not experienced identically. Whereas 26% and 23% of the subjects reported smelling "something" for the empty and distilled water bottles, 45% of the subjects reported smelling "something" for the propylene glycol solvent ($p < 0.02$). There were no differences between groups in reports of smelling "something." This rating was specifically designed to be vague so that reports of subtle experiences of olfaction would be potentially detected.

For ratings of intensity, a similar pattern was observed. Despite the fact that the ratings of intensity were tiny (using the scale 0 to 10, the average ratings for empty, distilled water, and propylene glycol were 0.7, 0.5, and 1.0), the solvent was rated as more intense ($p < 0.01$). Again, there were no significant differences between groups in reports of intensity.

For ratings of pleasantness, the picture is more complicated. On the average (across the three bottles), cacosmic subjects rated the bottles as slightly less pleasant than the noncacosmic subjects (–0.3 versus +0.4, $p < 0.04$). This effect was primarily due to slight ratings of unpleasantness for the nondepressed cacosmics (–0.8) compared to nondepressed noncacosmics (+0.7). Depressed cacosmics and depressed noncacosmics rated the bottles neutral on the average (0.1 and 0.1). Recall that the rating scale was –10 for unpleasantness to 0 for neutral to +10 for pleasantness. Hence, these group differences are very subtle, though they are reliable.

CONCLUSIONS

The pattern of findings obtained to date suggest that it may be possible to quantify subtle central nervous system effects to low-intensity chemicals in normals and cacosmics, and

hence individuals claiming to have multiple chemical sensitivities. The discovery that subtle differences in conscious experience can be revealed through careful assessment points to the care that must be taken in establishing concentrations of odors and assessing subjects guessing performance and subjective experience. Though one would expect that the EEG effects should be greater when patients are actually experiencing symptoms, because these effects would be confounded by the subjective experience the symptoms, the interpretation would be complicated. The use of low-intensity chemicals virtually eliminates this inherent complication.

In the cacosmia study reported above, the one-minute duration paradigm (rather than the paired sniff paradigm) was used in this preliminary study because we wanted subjects to experience the odors for a duration of time. The paired sniff paradigm developed for subthreshold olfactory testing needs to be applied to cacosmic subjects before definitive conclusions about EEG responses in the absence of conscious awareness can be drawn.

The use of computer controlled olfactometers may further improve the precision of the findings and conclusions. It is unclear whether spectral analysis and/or olfactory evoked potentials will prove more sensitive for assessing EEG registration of low-intensity chemicals.

Recall that the three bottles analyzed above in the cacosmia study were originally included in the design as "control" bottles to evaluate primary odors of interest (butanol in water and galaxolide in propylene glycol). Nonetheless, subjects differed in their EEG responses to the "control" bottles in a meaningful way (propylene glycol and water versus just an empty bottle). These data are consistent with the hypothesis that quantitative EEG methods may prove to be a sensitive and specific procedure for evaluating central nervous system sensitivity to different chemicals (propylene glycol and water versus air) at low-intensity levels. By using subthreshold concentrations of odorants without conscious sensory awareness, it should be possible to avoid using "masking" odors in future double-blind studies of chemical sensitivity.

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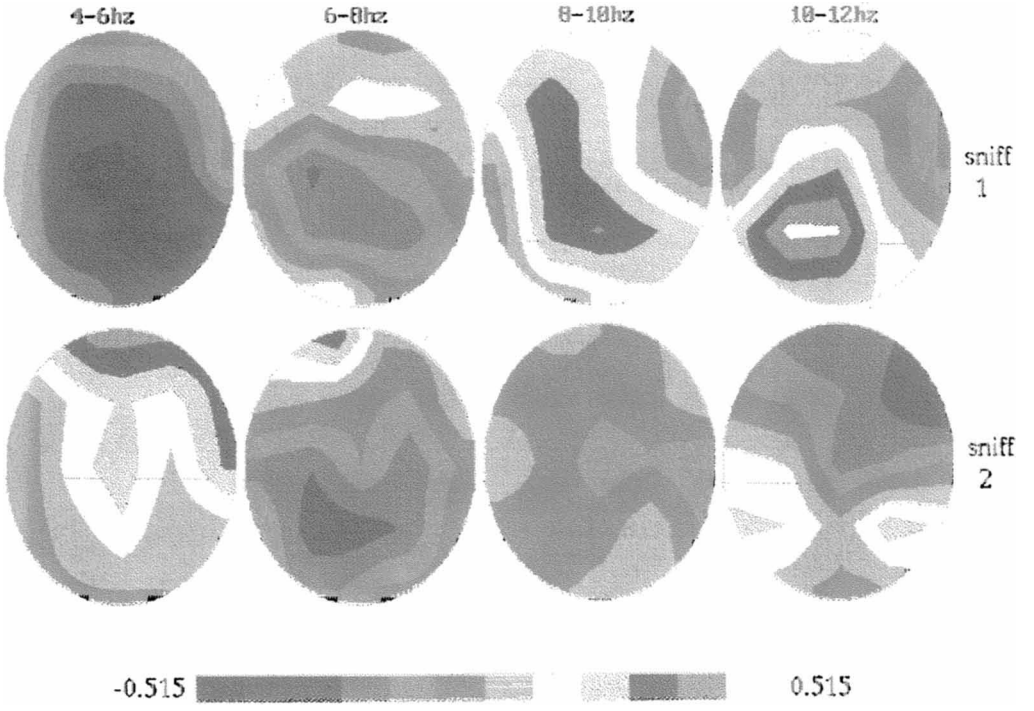

FIGURE 1. Topographic EEG maps subtracting control bottles from the odor bottles for subthreshold isoamyl acetate trials (n = 16) for 86 subjects. The top four maps reflect sniff one (the first sniff for the isoamyl acetate and control trials), the bottom four maps reflect sniff two (the second sniff for the isoamyl acetate and control trials). The four EEG bands (4–6 hz, 6–8 hz, 8–10 hz, 10–12 hz) are all drawn on the same scale. Reds and whites reflect increases in EEG, blues and blacks reflect comparable magnitude decreases in EEG. The top of each map reflects the front of the head, the bottom of each map reflects the back of the head.

Color Plate 2. As referenced in Schwartz et al., p. 637

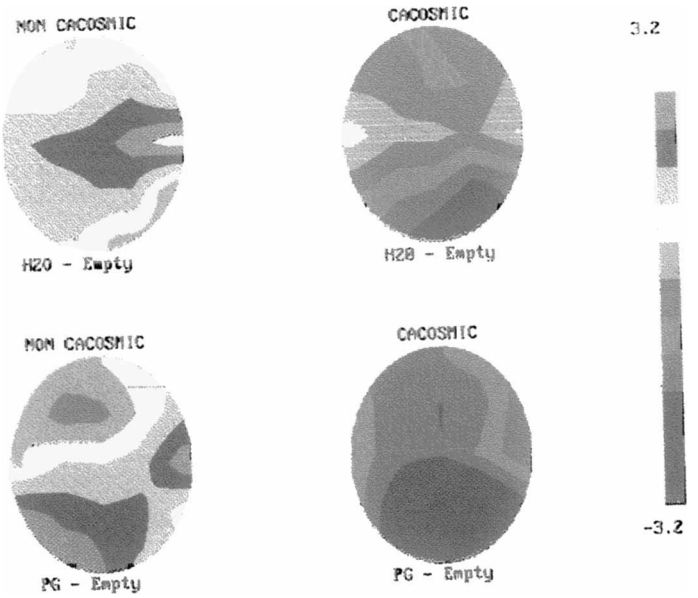

FIGURE 2. Distilled water minus empty bottle topographic EEG maps (top) and propylene glycol minus empty bottle topographic EEG maps (bottom) separately for noncacosmics (left) and cacosmics (right), averaged over depression, for low-frequency alpha (8–10 hz). Reds and whites reflect increases in EEG, blues and blacks decreases in EEG. The top of each map reflects the front of the head, the bottom of each map reflects the back of the head.

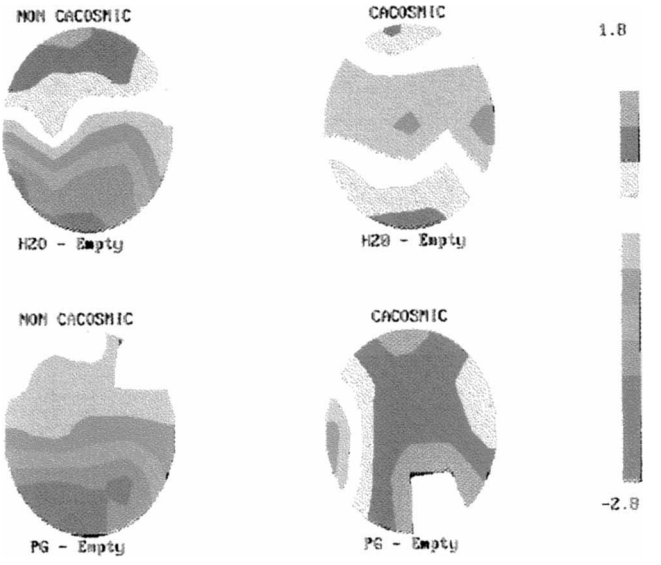

FIGURE 3. Distilled water minus empty bottle topographic EEG maps (top) and propylene glycol minus empty bottle topographic EEG maps (bottom) separately for noncacosmics (left) and cacosmics (right), averaged over depression, for low-frequency beta (12–16 hz). Reds and whites reflect increases in EEG, blues and blacks decreases in EEG. The top of each map reflects the front of the head, the bottom of each map reflects the back of the head.

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